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Calcium Foliar Sprays for Control of Alfalfa Greening, Cork Spot, and Hard End in 'Anjou' Pears

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ABSTRACT

New calcium (Ca) spray materials were made available to test for their possible improvement over the often-used dry form of calcium chloride products. Four orchards of mature 'Anjou' pears (*Pyrus communis* L.) were selected for the experiments. Three Ca materials were used at equal Ca rates, consisting of a dry Ca material derived from calcium chloride (Mora-leaf-Ca) with and without Sylgard; a liquid Ca material derived from $CaCl_2$ (Cal-Plex-12); and a dry Ca material derived from calcium oxide (Mira-Cal) at different concentrations. In one orchard, Mira-Cal Ca at the double rate had the lowest incidence of cork spot and hard end with the highest concentration of cortex Ca and acceptable fruit finish, closely followed by the standard rate of Mora-Leaf-Ca. In a second orchard, Mora-Leaf-Ca plus Sylgard 309 had the lowest incidence of cork spot and alfalfa greening. In the third orchard, Mora-Leaf-Ca had the lowest incidence of cork spot and the highest concentration of fruit Ca in peel and cortex. In the fourth orchard, Cal-Plex-12 Ca produced nearly complete control of cork spot and the highest concentration of fruit Ca in peel and cortex. When comparing commercial spray-machine application of 935 L ha^{-1}, control of cork spot and fruit Ca absorption was improved with six calcium applications versus only two spray applications.

Keywords: calcium sprays, pear fruit disorders, fruit quality

INTRODUCTION

Adequate calcium (Ca) is important for controlling many disorders of 'Anjou,' or 'Bartlett' pears (Ackley, 1954; Raese, 1980, 1989, 1999; Raese et al., 1979;

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Richardson and Lombard, 1979; Wilks and Welsh, 1965; Woodbridge, 1971). Calcium sprays are one method of decreasing the incidence of the majority of these disorders (Raese, 1988, 1989, 2001; Raese and Drake, 1995, 1996) and improving storability (Raese, 1999; Raese et al., 1999). However, from the very early trials of Ca sprays on 'Anjou' pears, there has been a serious concern about the possibility of blemishes on fruit due to various Ca sprays. In the beginning, Ca concentrations used for pears equaled those for apples, but apples were more resistant to spray blemishes. Therefore, reduced rates of Ca sprays on pears were evaluated with improved success (Raese and Stahly, 1982). New Ca formulations are constantly being developed and prior to recommendation all must be evaluated.

The objectives of this study were to determine the best Ca spray program, using new formulations, for controlling the various fruit disorders of 'Anjou' pears and its impact on quality.

MATERIALS AND METHODS

Three Ca spray materials were used: Mora-Leaf-Ca (34% Ca form $CaCl_2$, a dry material), Cal-Plex-12 (a liquid material, 12% Ca from $CaCl_2$), and Mira-Cal (a dry material, 30% Ca derived from calcium oxide).

The four 'Anjou' pear orchards used in the trials were located near Monitor, Cashmere, and Peshastin in Chelan County and Orondo in Douglas County, Washington, USA (2002). All trees were fully mature (20 + years).

Monitor Orchard

This orchard was selected because it had a history of cork spot. Five treatments were randomly assigned and replicated with eight single-tree plots in a randomized block design allowing for one or two guard trees and rows. Treatments included an unsprayed control, Mora-Leaf-Ca, Cal-Plex-12, and Mira-Cal at equivalent rates of Ca for each material and a double rate of Mira-Cal to determine possible spray injury to the fruit. Spray applications commenced in early June and were repeated at two-week intervals until two weeks before harvest, for a total of six sprays. A hand-gun sprayer was used and sprays were applied until runoff (approximately 20 L/tree).

Orondo Orchard

This orchard was selected because it had a history of very severe cork spot and alfalfa greening, and it was available for testing extraordinarily high rates of unknown Ca spray materials (Washington State University plots). Five treatments were randomly assigned and replicated with five single-tree plots in a randomized design allowing for guard trees. Treatments included an unsprayed control, three different Ca sprays (Mora-Leaf-Ca, Mora-Leaf-Ca + Sylgard 309, and Mira-Cal) at equivalent rates of Ca and Mira-Cal at four times the rate of other Ca sprays. Spray applications commenced in early June and were repeated at two-week intervals until two weeks before harvest, for a total of six sprays. A hand-gun sprayer was used and sprays were applied until runoff.

Cashmere Orchard

This orchard was selected to evaluate the three Ca spray products using a commercial sprayer at a rate of 935 L ha^{-1}. Three Ca spray treatments (Mora-Leaf-Ca, Cal-Plex-12, and Mira-Cal) were applied at equivalent Ca rates in a randomized strip block design with five double-tree plots. Treatments did not include an unsprayed control, as the remainder of the commercial orchard was sprayed with Ca sprays at the orchardist's discretion. However, a total of only two Ca sprays were applied for the season in June and July.

Peshastin Orchard

This orchard was also selected to test the three Ca spray products with a commercial sprayer at the rate of 935 L ha^{-1}. The three treatments consisted of Mora-Leaf-Ca, Cal-Plex-12, and Mira-Cal, all at equivalent Ca rates as recommended on the labels. The treatments were assigned in a randomized strip block design using five double-tree plots. The Ca spray commenced in early June and continued at two-week intervals for a total of six applications.

All samples were collected at commercial harvest, washed, weighed, and visually examined for fruit disorders and spray marks. Ten fruits from each sample were randomly selected for fruit Ca analysis at an independent commercial laboratory, which also prepared the samples for peel and cortex Ca analyses. After 60 d, 40 fruits were removed from regular atmosphere storage (1°C). These 40 fruits were used to evaluate fruit disorders and spray marks. Visual disorders and spray marks were expressed as percent affected fruit. Twenty fruits were used to evaluate fruit firmness, soluble solids concentration (SSC), titratable acidity (TA), and fruit weight immediately after removal. Firmness was determined with the TA-XT2 texture analyzer (Texture Technologies, Scarsdale, NY) equipped with a 7.8 mm probe, and values were reported in Newtons (N). SSC and TA were determined from an aliquot of juice expressed from a cross-sectional slice from each of 10 fruits. An Abbe-type refractometer with a sucrose scale calibrated at 20°C was used to determine SSC. TA was measured with a radiometer titrator, model TTT85 (Radiometer, Copenhagen). Acids were titrated to pH 8.2 with 0.1 *N*, NaOH, and expressed as percent malic acid.

RESULTS AND DISCUSSION

Monitor Orchard

Hard end and cork spot were the primary fruit disorders in this orchard. It was noted that the lowest incidence of hard end occurred in the unsprayed control trees, while the lowest incidence of cork spot occurred in trees sprayed with Mora-Leaf-Ca or the double rate of Mira-Cal (Table 1). However, the severity of cork spot was highest in the unsprayed control trees and least severe in those under the Mora-Leaf-Ca or Mira-Cal (2×) treatments. Highest Ca concentrations in peel plus cortex samples also occurred in the Mora-Leaf-Ca and both Mira-Cal treatments.

It should be noted that the ratio between peel Ca and cortex Ca was lowest for the control fruit and the double rate of Mira-Cal treated fruit. These two treatments (control and Mira-Cal) had the lowest incidence of black end (hard end) (Table 1). This disorder was positively correlated ($r = 0.644$, 1% significance) with the peel Ca:cortex Ca ratios. This result also suggests that fruit affected with hard end may be deleterious to Ca-spray penetration (a little-known supposition) because peel Ca concentrations were higher than those of cortex Ca relative to the unsprayed control fruit. If this is the case, it may explain why trees affected with hard-end fruit may be more difficult to correct fully with Ca sprays than those with other low-Ca fruit disorders. Hard end may require higher rates or more frequent Ca sprays, which was evident under the high rate of Mira-Cal in the Monitor orchard.

Fruit size was not affected by Ca sprays (Table 1). However, Ca spray marks on fruit were slightly less noticeable on fruit from trees sprayed with Mira-Cal, even at the double rate. This result is important because pear fruit are quite sensitive to Ca sprays. It is noteworthy that the most desirable appearing fruit was borne by trees receiving no Ca spray treatments. This result is unusual, but is likely because the control trees exhibited the lowest incidence of hard end. Further fruit quality measurements indicated no difference among treatments for fruit firmness, soluble solids, or titratable acidity.

Orondo Orchard

The primary fruit disorders in this orchard were alfalfa greening and cork spot (Table 2). The highest incidence of these two disorders occurred in fruit from the unsprayed control trees, while the lowest incidence occurred in fruit sprayed with Mora-Leaf-Ca plus Sylgard. However, the highest concentration of Ca in fruit peel and cortex occurred in the unsprayed control fruit. This result could be due to the small size of the control fruit. Fruit Ca concentrations are frequently higher in smaller fruit.

Table 1

Effect of calcium sprays on fruit disorders, fruit calcium, fruit weight, calcium spray injury, and fruit quality of ‘Anjou’ pears, Monitor, WA

Calcium Spray treatment	Rate per 100 L	Hard end (%)	Cork spot (%)	Cork severity (no. of corks)	Peel+ cortex Ca/2 (ppm)	Peel Ca cortex Ca ratio	Fruit Wt (g)	Ca spray injury (1–10)*	Fruit appearance (1–8)*	Fruit Firmness (N.)
Control	0	2.8 b[z]	8.1 a	1.16 a	930 b	3.30 c	208 a	0.2 b	6.1 a	59.6 a
Mora-Lf-Ca	120 g	14.7 a	5.3 a	0.63 c	1039 a	3.58 bc	213 a	1.2 a	5.4 a	60.0 a
Cal-Plex-12	264 ml	15.0 a	8.1 a	0.76 bc	950 b	3.82 ab	211 a	1.0 a	5.8 a	60.5 a
Mira-Cal	137 g	15.3 a	11.9 a	0.83 b	1016 a	3.94 a	205 a	0.7 ab	5.2 a	60.5 a
Mira-Cal	274 g	8.1 b	4.7 a	0.44 d	1022 a	3.25 c	198 a	0.8 ab	5.5 a	60.0 a

[z]Mean separation within columns by Duncan’s multiple range test ($P \leq 0.05$).

Calcium spray injury evaluated on a scale of 1 to 10 (1 = very slight, 3 = borderline acceptable, 10 = severe).

Fruit appearance evaluated on a scale of 1 to 8 (1 = very poor, 8 = excellent).

Table 2

Effect of calcium sprays on fruit disorders (alfalfa greening and cork spot), fruit calcium, fruit weight, calcium spray injury, pear psylla, and russett marks of 'Anjou' pears, Orondo, WA

Calcium Spray treatment	Rate per 100 L	Alfalfa greening (%)	Cork spot (%)	Peel + cortex Ca/2 (ppm)	Peel/cortex Ca ppm (ratio)	Fruit Wt (g)	Ca spray injury (1–10)*	Fruit appearance (1–8)*	Psylla (1–10)*	Russet (1–10)*
Control	0	18.2	43.4 a[z]	1061 a	3.57 c	181 c	0.8 b	4.0	3.3 b	2.7 a
Mora-Lf-Ca	120 g	10.1	34.8 ab	958 b	6.42 a	184 c	1.8 a	3.6	3.9 ab	2.9 a
Mora-Lf-Ca+ Sylgard	120 g +10 ppm	2.3	14.1 c	902 b	4.63 b	207 a	1.8 a	4.4	3.9 ab	2.7 a
Mira-Cal	137 g	10.5	20.7 bc	923 b	3.97 bc	192 b	1.6 ab	3.6	4.6 a	2.8 a
Mira-Cal	547 g	15.3	28.5 ab	895 b	3.83 c	190 b	2.0 a	3.6	4.1 ab	2.8 a

[z]Mean separation within columns by Duncan's multiple range test ($P \leq 0.05$).
Calcium spray injury evaluated on a scale of 1 to 10 (1 = very slight, 3 = borderline acceptable, 10 = severe).
Fruit appearance evaluated on a scale of 1 to 8 (1 = very poor, 8 = excellent).
Fruit psylla and russet marks evaluated on a scale of 0 to 100% (1 = 10%, 10 = 100%).

Table 3

Effect of calcium sprays and amount on fruit disorders, fruit calcium, fruit weight, calcium spray injury, and fruit quality of ‘Anjou’ pears, Cashmere and Peshastin, WA

Calcium spray treatments	Rate per 935 L · ha^{-1}	Cork spot (%)	Peel Ca (ppm)	Cortex Ca (ppm)	Fruit wt (g)	Injury (1–10)	Appearance (1–8)*	Firm. (N)	SSC (%)	Total acids
				Peshastin Orchard (6×)						
Mora-Lf-Ca	4.5 Kg	1.2 c	1486 ab	414 b	238 a	1.5 ab	7.1 a	61.8 a	13.4 abc	0.37 cd
Cal-Plex-12	9.35 L	0.8 c	1566 a	449 a	238 a	1.3 b	7.2 a	58.7 b	13.5 b	0.34 d
Mira-Cal	5.06 Kg	2.8 b	1528 a	407 b	210 b	1.3 b	6.9 a	61.4 ab	13.3 bc	0.41 ab
				Cashmere Orchard (2×)						
Mora-Lf-Ca	4.5 Kg	3.0 b	1356 bc	353 c	219 ab	1.4 ab	7.2 a	63.2 a	13.2 bc	0.42 a
Cal-Plex-12	9.35 L	4.1 a	1182 d	318 d	221 ab	1.7 a	7.2 a	60.9 ab	13.1 c	0.37 bc
Mira-Cal	5.06 Kg	5.3 a	1300 c	313 d	212 b	1.0 c	7.0 a	62.7 a	13.7 a	0.39 abc

[z]Mean separation within columns by Duncan’s multiple range test ($P \leq 0.05$).
Calcium spray injury evaluated on a scale of 1 to 10 (1 = very slight, 3 = borderline acceptable, 10 = severe).
Fruit appearance evaluated on a scale of 1 to 8 (1 = very poor, 8 = excellent).
Fruit psylla and russet marks evaluated on a scale of 0 to 100% (1 = 10%, 10 = 100%).

It should be noted that the lowest peel Ca/cortex Ca ratio occurred in the control fruit (Table 2). Control fruit also had fewer markings than the Ca-sprayed fruit due to pear psylla (*Psylla pyricola* Foerster) and russeting, possibly due to pear leaf blister mites (*Eriophyes pyri* Pagenstecher) and the pear rust mite (*Epitrimerus pyri* Nalepa). Fruit russeting is reported to occur when the above two mite species are not controlled (Williams et al., 1978). The greater number of markings on the Ca-sprayed fruit plus the higher peel Ca/cortex Ca ratios suggest that russeted fruit were more difficult to penetrate with Ca sprays because peel and cortex Ca concentrations were negatively correlated with the severity of fruit russeting ($r = -0.911$, significant at 0.001). Spray injury from the high rate (4×) of Mira-Cal was acceptable and only slightly higher than that from the other Ca-spray treatments. Due to the poor condition of the fruit, including codling-moth worm damage, no further quality measurements were taken.

Cashmere and Peshastin Orchards

The incidence of cork spot was lower in fruit from trees sprayed six times with Ca sprays in the Peshastin orchard than in fruit sprayed only two times in the Cashmere orchard (Table 3). In both orchards, Mora-Leaf-Ca or Cal-Plex-12 appeared to control cork slightly better than did Mira-Cal. However, Mira-Cal–treated fruit had the fewest spray markings.

Calcium concentrations in fruit were highest from trees receiving six sprays from the Peshastin orchard and lowest in fruit sprayed twice with Cal-Plex-12 or Mira-Cal from the Cashmere orchard (Table 3). Highest Ca concentrations occurred in fruit from trees sprayed six times with Cal-Plex-12, and this was also the treatment showing the lowest incidence of cork spot. Highest fruit firmness and titratable acidity occurred in fruit from trees in the Cashmere orchard sprayed with Mora-Leaf-Ca, while the highest soluble solids occurred in the Mira-Cal-sprayed fruit from the Cashmere orchard.

CONCLUSIONS

Calcium sprays are important for reducing fruit disorders in ‘Anjou’ pears. While calcium chloride-type sprays remain dominant in controlling fruit disorders and increasing fruit Ca concentrations, the new Ca spray material, Mira-Cal, showed promise at higher rates for increasing fruit Ca and reducing fruit disorders without causing major fruit spray markings. It appears that keeping fruit clean from russeting problems is advantageous for Ca spray penetration. Possible obstruction of Ca spray adsorption by hard-end-affected fruit should be determined.

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